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# EVALUATION OF AIRBORNE TELEMETRY ANTENNAS FOR USE IN UHF TELEMETRY BANDS

by

V. R. Christenson
Systems Development Department

ABSTRACT. This report documents the results of a program conducted to evaluate experimental and commercially available UHF airborne antennas for use in the 1435-1535 and 2200-2300 MHz telemetry bands. The evaluation established that a wrap-around type antenna gives satisfactory performance and is adaptable for use in several different missile configurations. The design and operational characteristics of each antenna evaluated in a missile configuration are presented, together with typical antenna patterns and VSWR data obtained during the program.



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## FOREWORD

As part of the Navy's scheduled conversion from VHF to UHF for test range operations, the Naval Weapons Center conducted a program for the development of a universal UHF antenna system that could be adapted to any missile and provide antenna patterns that would give satisfactory air-to-ground missile coverage. Several different types of commercially available and experimental wide-band UHF airborne telemetry antennas were evaluated and it was demonstrated that a wrap-around type antenna, using stripline or microstripline techniques, is applicable to several missile configurations and offers the best solution to operation in the assigned 1435-1535 MHz and 2200-2300 MHz telemetry bands.

This report describes the configurations and gives typical performance data of the wrap-around antennas evaluated, and indicates the designs that are acceptable for the intended purpose. The work was done during the period June 1967 to December 1970 under AirTask A05-535-222/216-1/F99-05-01.

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Much of the information presented in this report was compiled through the combined efforts of J. J. Allen and R. E. Rockwell in a preliminary report published as Technical Note 3060-68-04, dated September 1968.

# INTRODUCTION

Since early 1966, as a result of the planned conversion from VHF to UHF operation on Navy test ranges, the Naval Weapons Center has been engaged in a program for the development of airborne antennas that would operate in the newly assigned 1435-1535 MHz and 2200-2300 MHz UHF telemetry bands. This required a new concept in airborne telemetry antenna design, in answer to which NWC personnel at China Lake and Corona* originated the concept of a wrap-around belt type antenna that could be used on almost all missile configurations.

Subsequently, a contract was let to the AVCO Corporation for the development of a wrap-around antenna using stripline techniques, under the direction of William Haigh. Mr. Haigh later formed his own company and, since the wrap-around stripline antennas are now being produced by Haigh Associates, this design is referred to as the Haigh antenna. Antenna development contracts were also awarded to Litton Systems and the Ball Brothers Research Corporation while in-house development continued at Corona.

Different design approaches were taken by the several developers. The Haigh antenna uses a stripline design, the Ball Brothers and Corona antennas use a microstripline design, and the Litton antenna is a dielectrically loaded waveguide with crossed slots along the wall edge. Line drawings of the different designs are shown in Fig. 1 and 2.

## STRIPLINE AND MICROSTRIPLINE DESIGN

Figure 1 depicts both the stripline and microstripline designs of a wrap-around antenna. In the stripline configuration, representing the Haigh antenna, the center conductor is shown surrounded by a homogeneous dielectric medium structured between two ground planes. The microstripline configuration, representing the Ball Brothers antenna, has one ground plane and the center conductor is partially surrounded by a dielectric medium. If the top of the microstrip conductor were covered with a dielectric medium, we would then have the configuration of the NWC Corona design. Design equations are somewhat modified from one configuration to the other.

*The Corona personnel involved have since transferred to the Naval Missile Center, Point Mugu (Code 5370).

## CROSSED-SLOT DESIGN

Figure 2 depicts the crossed-slot design of the Litton antenna. The crossed slots, which are used as radiating elements in the broad wall of the waveguide, are excited by traveling waves within the waveguide. The pattern quality obtained with this design was poor; therefore, it is not recommended for airborne applications unless improvements can be made that will optimize antenna performance.

## ANTENNA-PATTERN MEASUREMENT PROCEDURE

The patterns of the different antennas were measured at the NWC microwave anechoic chamber at China Lake, with the test antenna mounted on a dummy missile airframe. The missile coordinate system is shown in Fig. 3; the test setup for antenna-pattern recording is shown in Fig. 4.

This report presents typical VSWR plots and antenna patterns obtained during the evaluation tests and summarizes the progress of wrap-around antenna development.

## SUMMARY OF TEST RESULTS

In addition to the wrap-around antennas discussed, blade antennas and other types that protrude from the missile skin were investigated during this evaluation program. However, for aerodynamic characteristics and missile handling, the wrap-around belt type has proved to be the most effective design that can be adapted to most missile configurations. The evaluation has established that the Haigh, Ball Brothers, and Corona versions of the wrap-around system are all acceptable for the intended use. The Litton crossed-slot design did not meet performance specifications. However, with further study, this version could possibly be improved to operate at a proper level of performance.

The approved antennas will handle RF power inputs of 20 watts under extreme environmental conditions, such as altitudes of 100K feet and temperatures of -55° C to +125° C. The Haigh antenna has withstood the environment of an actual missile firing with no loss of telemetry data. A VSWR of 2:1 is satisfactory, and antenna gain of -5 dB is nominal for these antennas, all of which can be designed for both L and S band frequencies and constructed with thicknesses of 1/16-inch and 1/8-inch and widths to a minimum of three inches.

Brief descriptions of the wrap-around antennas evaluated are presented in the following paragraphs.

### HAIGH ANTENNA

The Haigh antenna, which comprises a stripline eight-slot array (Fig. 5), was the first of the wrap-around type to be developed. This system, which has proved to be very successful, is designed to fit almost all missiles of varying diameters, such as 5, 8, and 10 inches, and can be flush-mounted on the missile skin. Its development has progressed so that it can also be designed for use at frequencies outside the UHF telemetry bands. The antenna is horizontally polarized, and the radiation pattern is omnidirectional. Figure 6 shows the system mounted on the telemetry section of a Shrike missile.

A plot of typical VSWR data obtained with the Haigh antenna is shown in Fig. 7, and typical antenna patterns, measured using a mockup of a typical missile configuration, are shown in Fig. 8 and 9. The average antenna gain, referenced to isotropic as shown in Fig. 8, is about -4.5 dB.

Several captive flight tests, during which the aircraft simulated typical missile-launch maneuvers, were also conducted to demonstrate the tracking capability of a ground-based auto-track antenna. Good signal strength was received from the airborne antenna. The Haigh antenna was also used for an actual Shrike missile firing. Data reception, using a ground-based auto-track antenna was 100% to missile impact.

Another version of the Haigh antenna is in use on a 10-inch diameter instrumentation pod. This antenna (Fig. 10) is a half-wrap version of the same configuration as the full wrap-around belt type antenna. Two half-wrap antennas--one for a frequency of 1700-1800 MHz, and the other for a frequency of 2200-2300 MHz--were designed specifically for captive flight tests in which the antenna radiation pattern need only be in the lower hemisphere.

A plot of half-wrap antenna VSWR data is shown in Fig. 11; antenna patterns are shown in Fig. 12 through 14.

## BALL BROTHERS ANTENNA

The antenna designed by the Ball Brothers Research Corporation uses microstrip techniques for feeding the radiating elements (Fig. 15). It is a wrap-around type and has the same physical shape as that of the Haigh system. The Ball Brothers system has been used on missiles of various diameters and can also be designed for operation at frequencies outside the UHF telemetry band. The antenna is polarized horizontally; the radiation pattern is omnidirectional.

A plot of VSWR data for this antenna is shown in Fig. 16; antenna patterns are shown in Fig. 17 and 18. The average antenna gain, referenced to isotropic as shown in Fig. 17, is about -5 dB.

This antenna is satisfactory for airborne use and is presently being improved so that the radiation pattern will be more omnidirectional.

## LITTON ANTENNA

The Litton system (Fig. 19) is a dielectrically loaded waveguide formed in the same shape as the Haigh and Ball Brothers systems. It is fed by a coaxial line with a TNC connector, and the radiating elements are crossed slots in the broad wall of the waveguide. The crossed slots are excited by traveling waves within the waveguide. The antenna is circularly polarized and the radiation pattern is omnidirectional in the azimuth plane.

Since the VSWR data (Fig. 20) and the antenna patterns produced by the crossed-slot system (Fig. 21 and 22) were not satisfactory, antenna gain was not measured.

Although Litton intended to develop an improved version of the crossed-slot design, no further work has been done to date, and the antenna in its present design is not recommended for airborne applications.

## NWC CORONA (NWCC) ANTENNA

The wrap-around antenna developed at NWC Corona (Fig. 23) uses microstrip techniques similar to those used in the Ball Brothers antenna and has essentially the same physical shape. The circuitry is not visible in the figure since it is covered with a dielectric material. In microstrip circuits, air or solid dielectric may be used on the side on which no ground plane exists. The radiant field pattern of the antenna, which has four radiating elements and is horizontally polarized, has better omnidirectional characteristics than the previously discussed designs.

A plot of the VSWR data is shown in Fig. 24; antenna patterns, measured on a dummy missile airframe, are shown in Fig. 25 and 26. The average antenna gain, referenced to isotropic as shown in Fig. 25, is about -5.0 dB.

# CONCLUSIONS AND RECOMMENDATIONS

Of all the airborne antennas evaluated, the Haigh wrap-around belt-type system is the one in most general use at NWC at this time. This antenna is essentially universal in that the full wrap-around version has been used with satisfactory results on the mockup missile configuration and in a flight test of the Shrike missile, and the half-wrap version is operating satisfactorily on a 10-inch instrumentation pod.

It is recommended that belt-type antennas be used for missiles of small diameter for the following reasons:

- Ease of missile handling, since there are no protrusions, which also allows the missile to be tube-launched.
- No phasing harness or circuitry required inside the missile, allowing more room for other missile circuitry.
- Less aerodynamic disturbance since antenna can be flush-mounted to the missile skin.
- Has good omnidirectional pattern, which minimizes data loss regardless of attitude during launch and flight trajectories.
- Ease of installation and interchangeability for different frequency operation.
- Relatively low cost in quantities, and availability from two or more sources.

- Not limited for use in the UHF telemetry band.
- Antenna is presently being used successfully on several types of missiles.

Further information can be obtained by writing to Commander, Naval Weapons Center (Code 306), China Lake, California 93555.

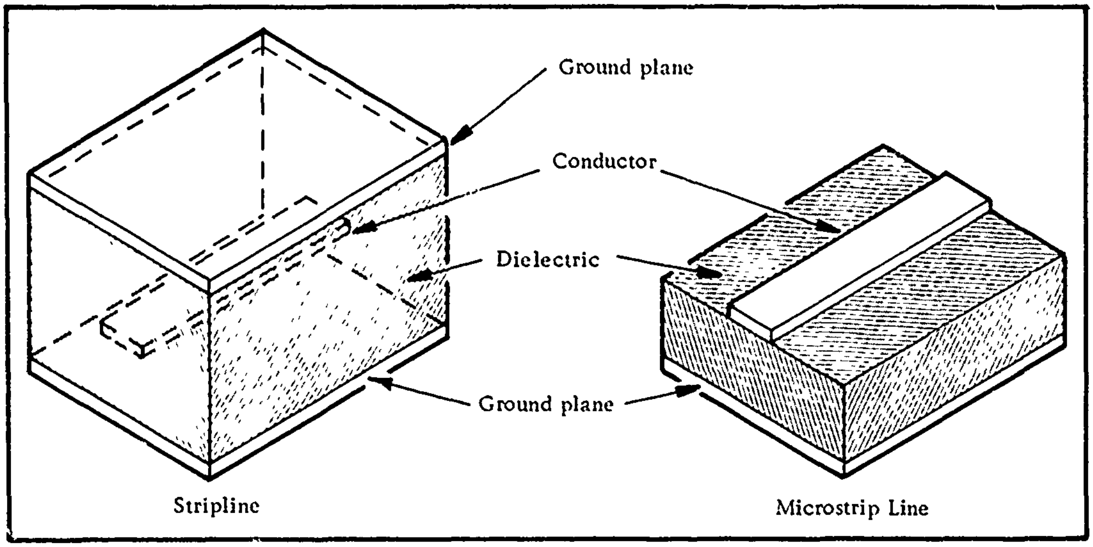



FIG. 1. Comparison of Stripline and Microstripline Configurations.

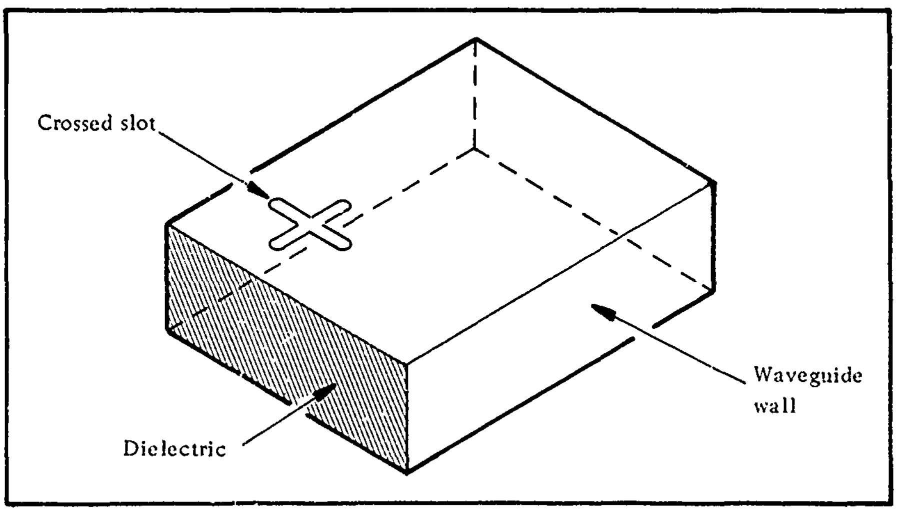



FIG. 2. Crossed Slot in the Broad Wall of a Dielectric Loaded Waveguide.

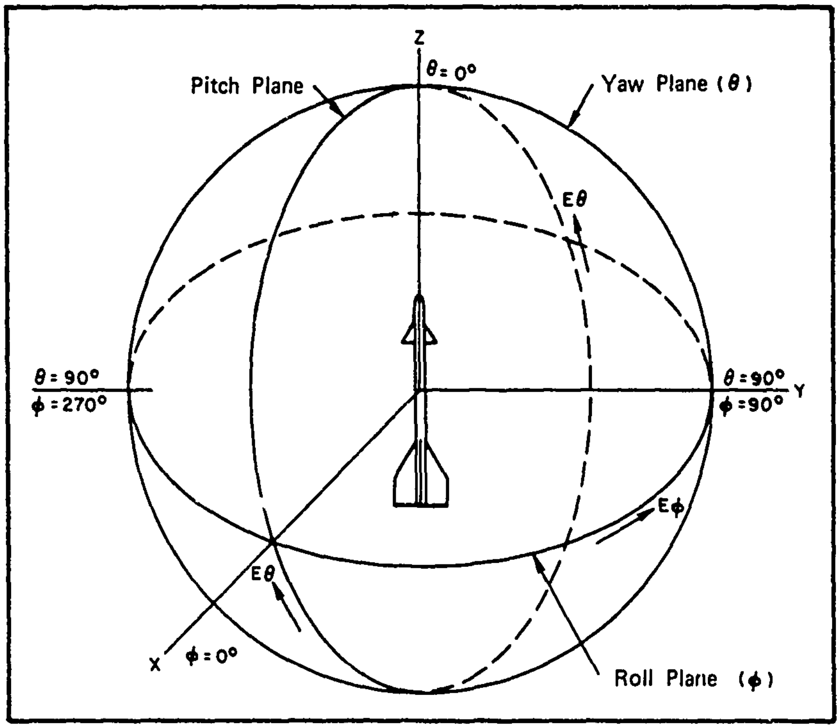



FIG. 3. Missile Coordinate System.

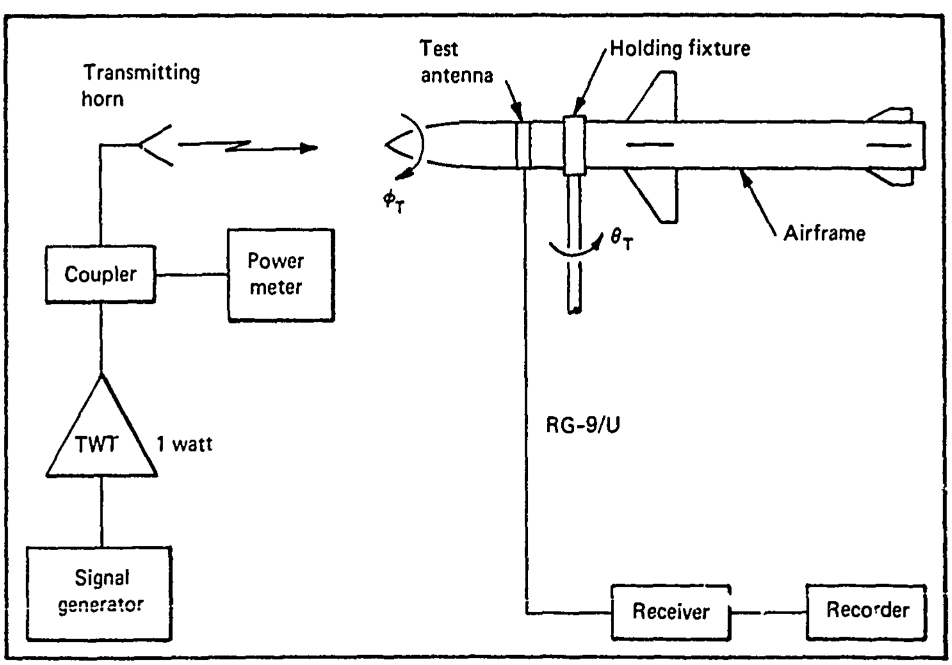
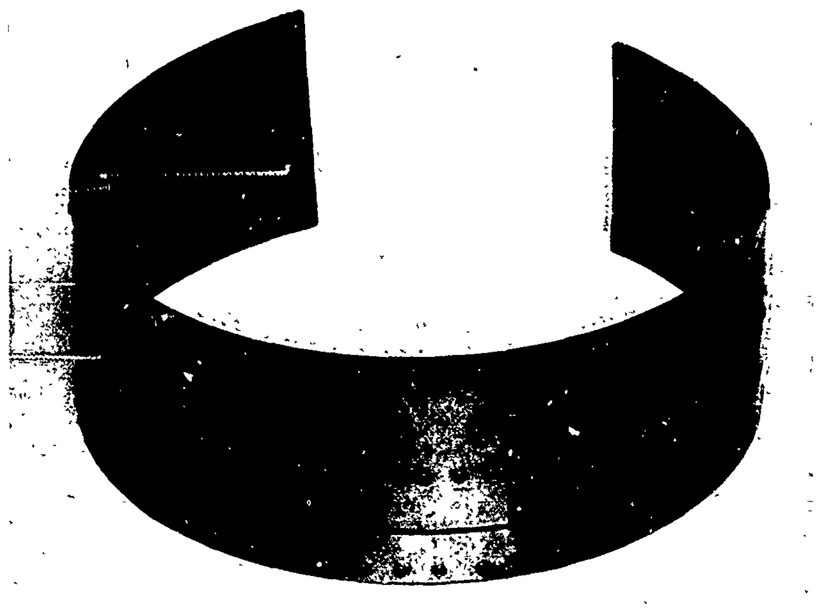
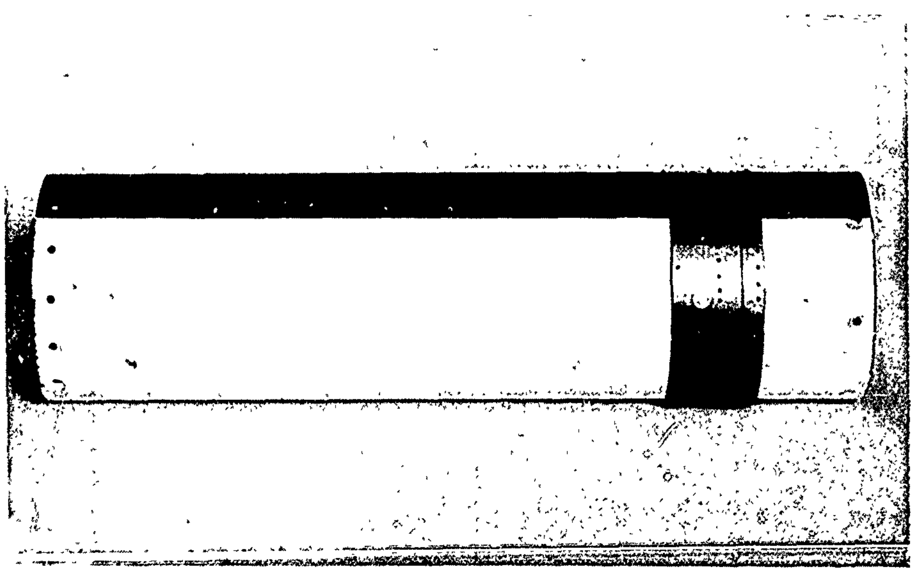



FIG. 4. Test Setup for Pattern Measurements of Wrap-Around Antennas.



LHL 134971

FIG. 5. Haigh Wrap-Around Antenna.



LHL 134197

FIG. 6. Haigh Antenna Installed on TM Section of Shrike Missile.

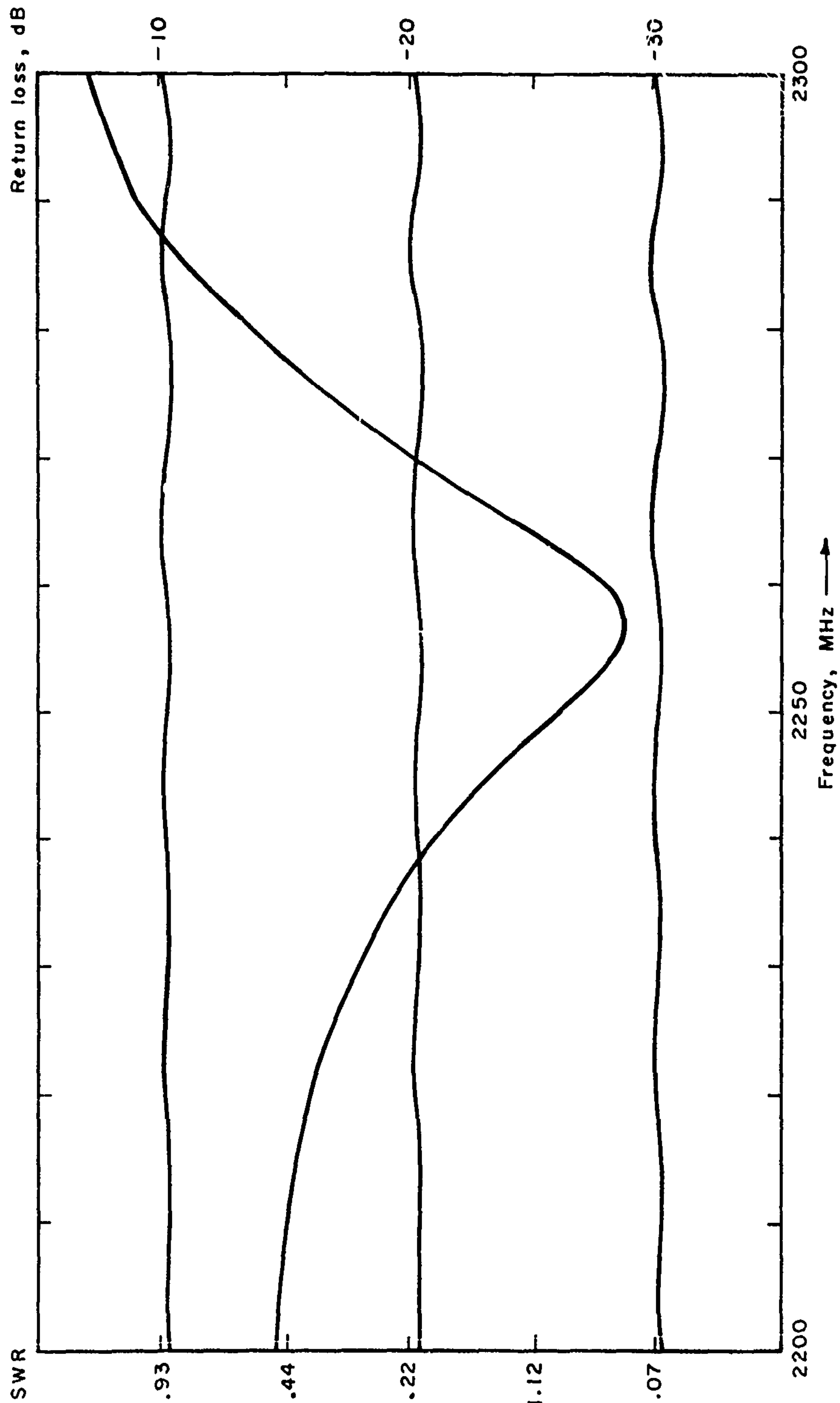



FIG. 7. VSWR/Return Loss of Haigh Antenna.

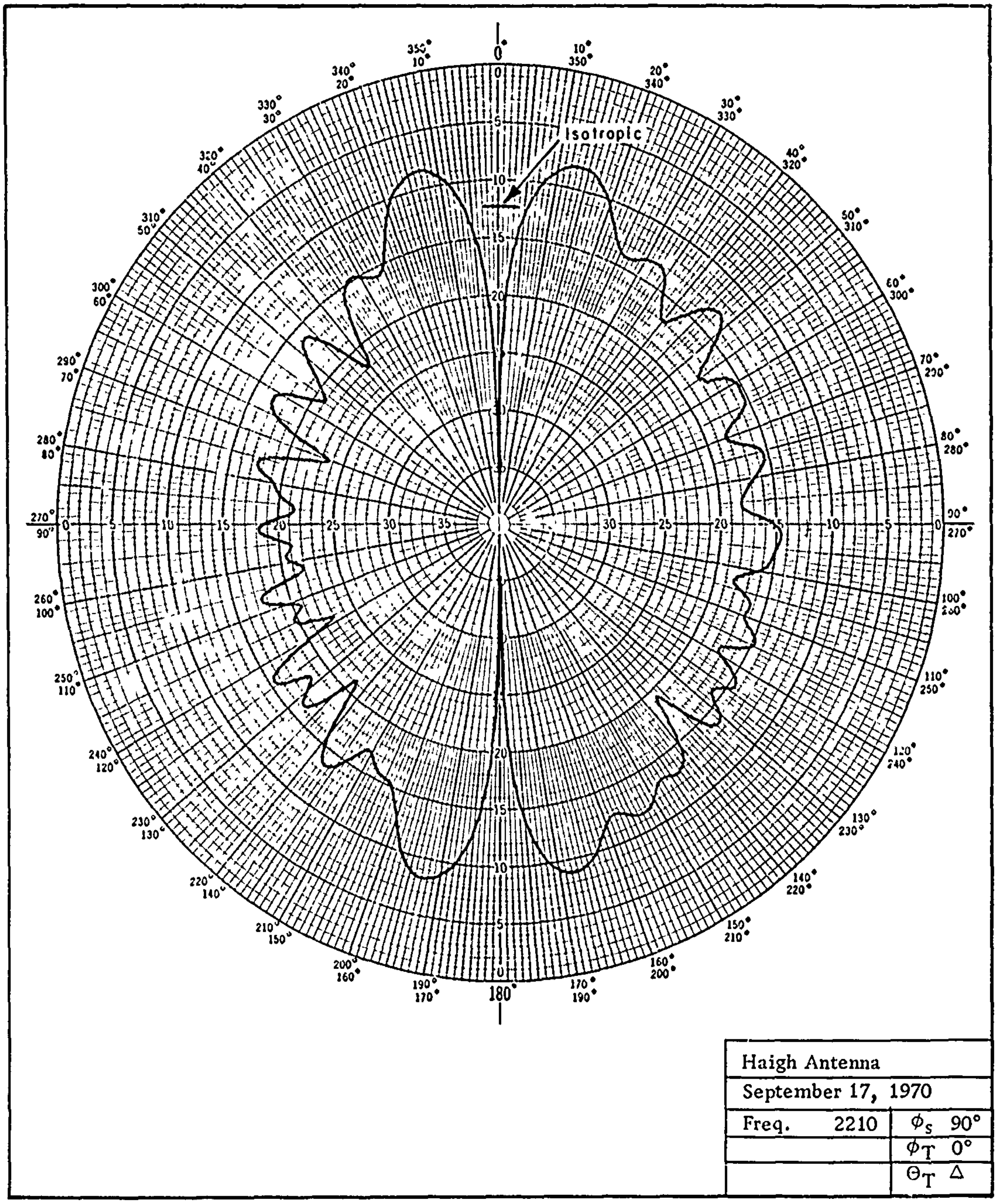
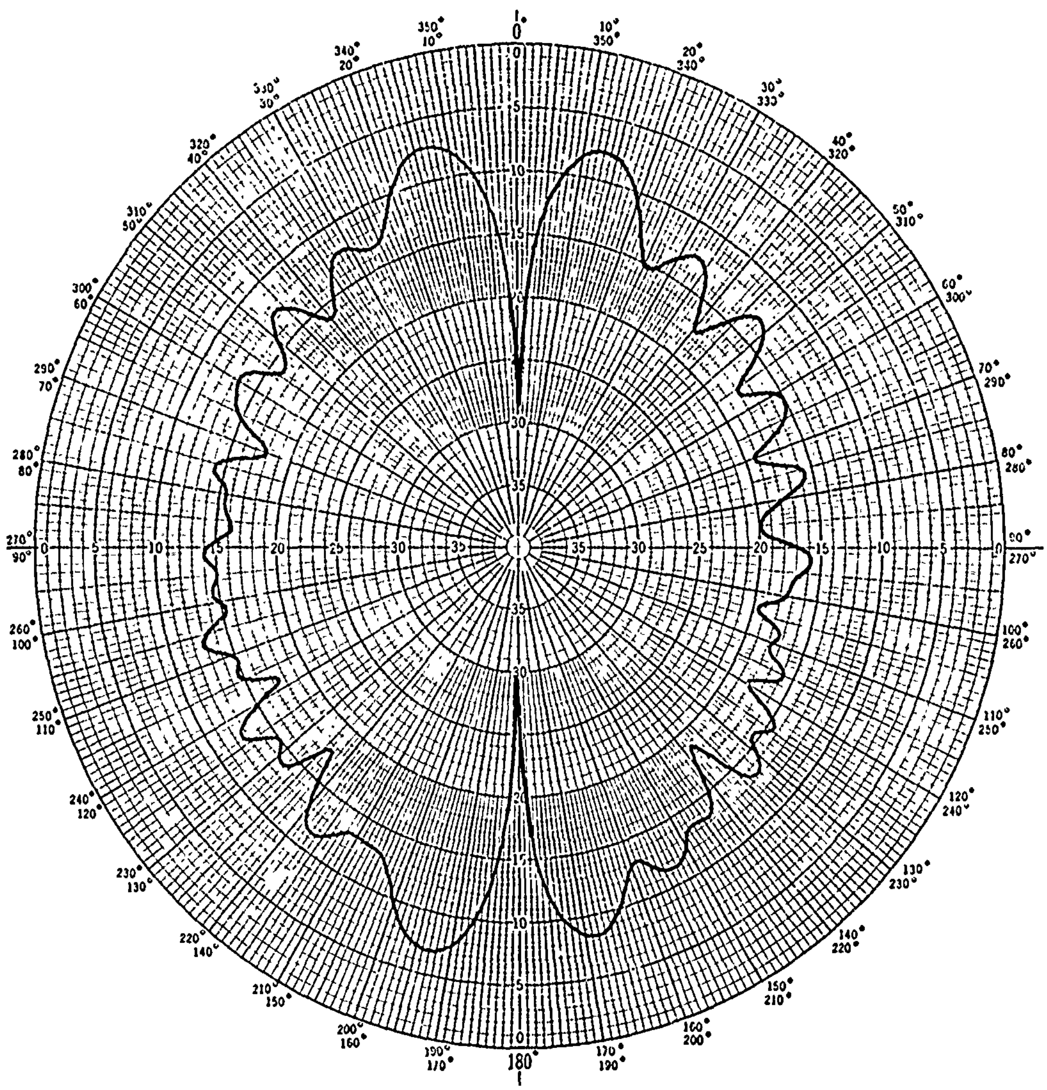


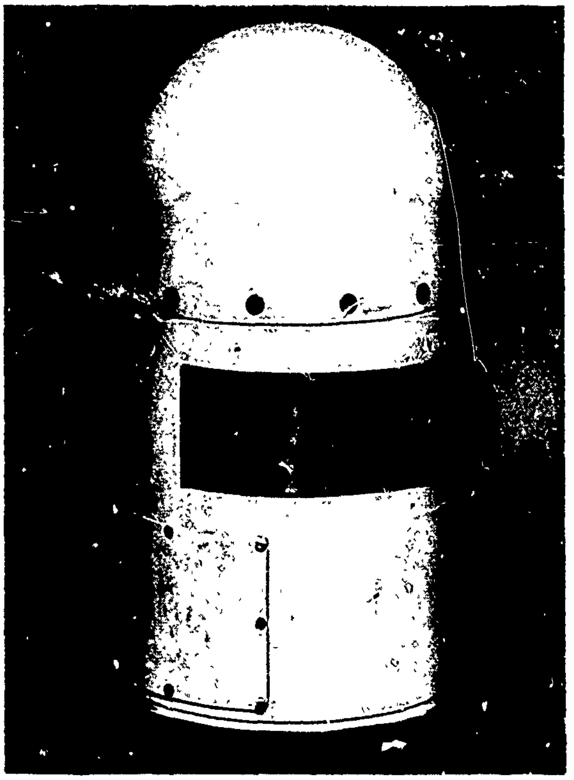

FIG. 8. Haigh Wrap-Around Antenna Yaw Plane Pattern.



| Haigh Antenna | |
| --- | --- |
| September 17, 1970 | |
| Freq. 2210 | $\phi_S$ 90° |
| | $\phi_T$ 270° |
| | $\Theta_T$ Δ |

FIG. 9. Haigh Wrap-Around Antenna Pitch Plane Pattern.

FIG. 10. Haigh Half-Wrap Antenna.



LHL 153904

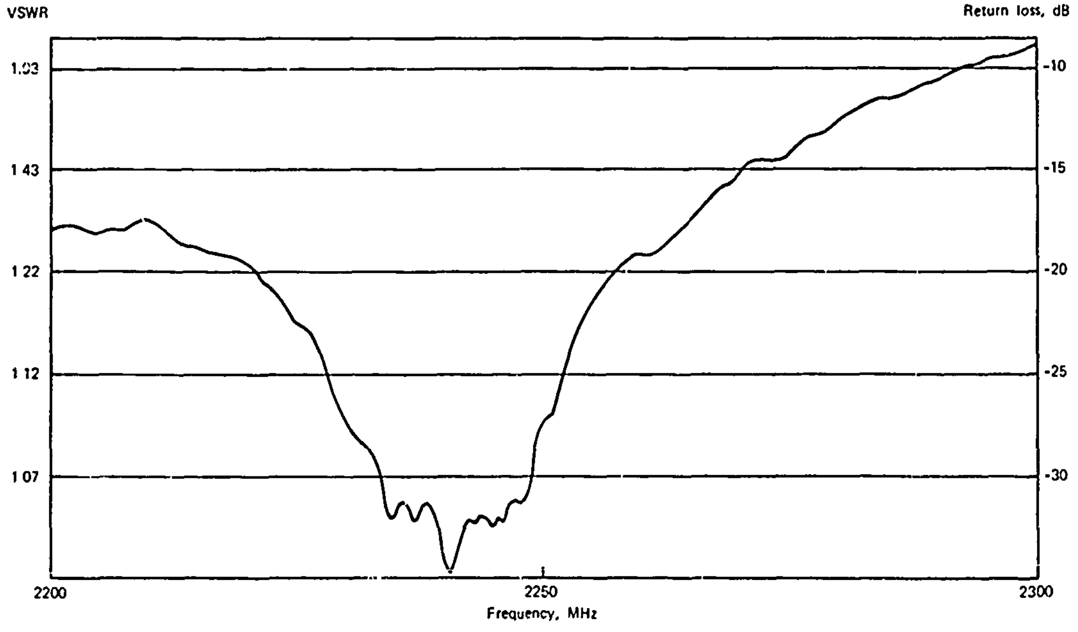
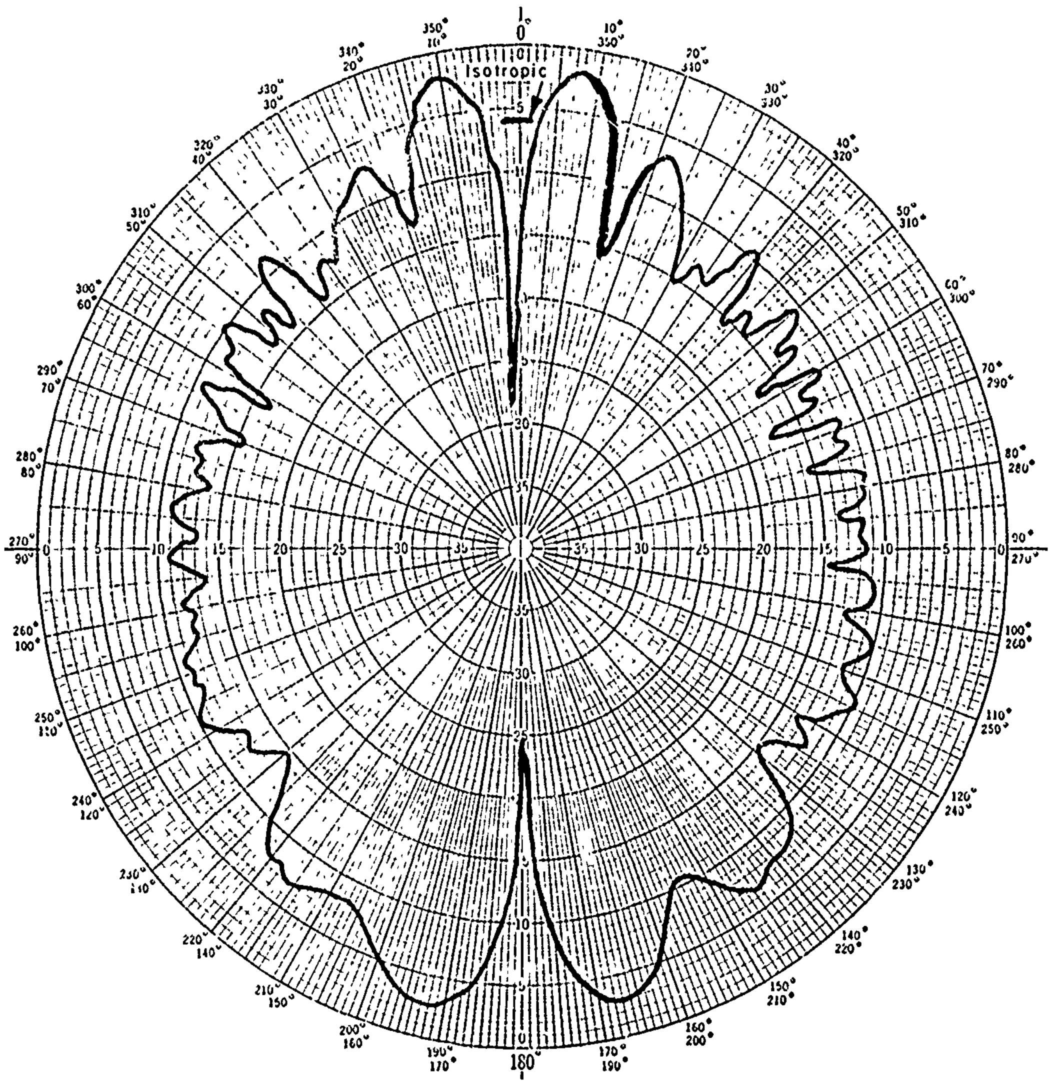



FIG. 11. VSWR/Return Loss of Half-Wrap Antenna.




| | | |
|---|---|---|
| Haigh Antenna | | |
| December 16, 1970 | | |
| Freq. | 2270 | $\phi_S$ 90° |
| | | $\phi_T$ 0° |
| | | $\Theta_T$ Δ |

FIG. 12. Haigh Half-Wrap Antenna Yaw Plane Pattern.

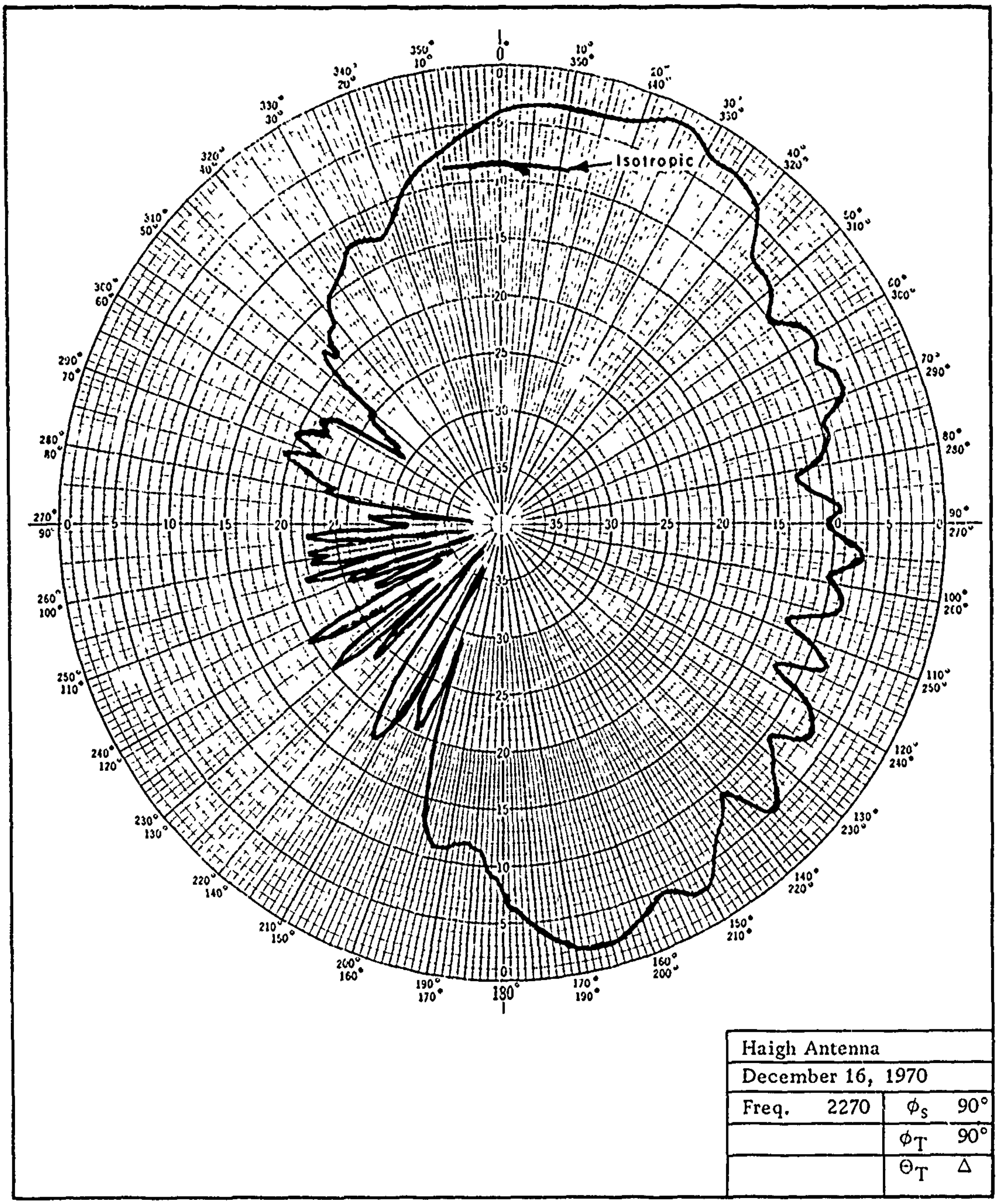
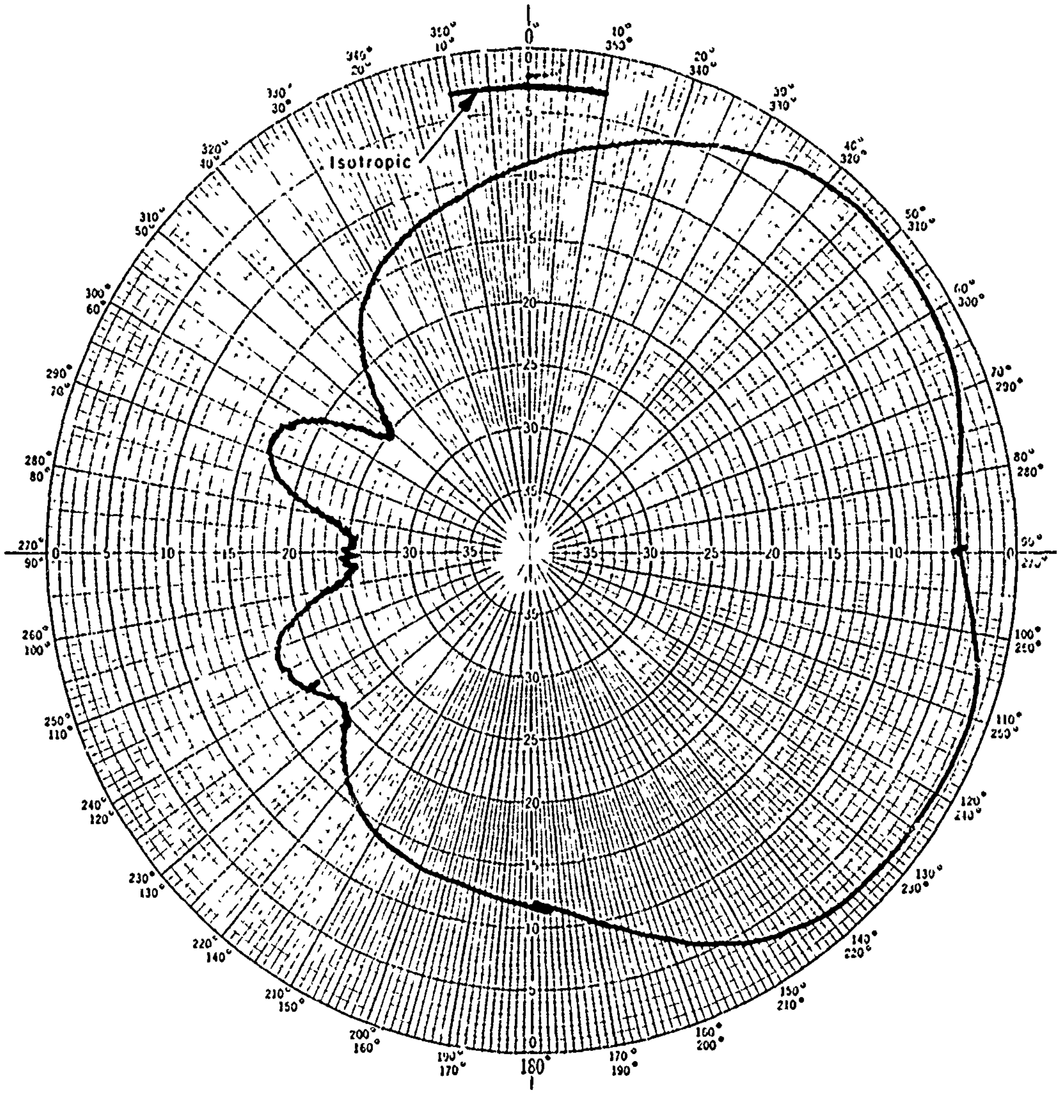



FIG. 13. Haigh Half-Wrap Antenna Pitch Plane Pattern.




| Haigh Antenna | | | |
|---|---|---|---|
| December 16, 1970 | | | |
| Freq. | 2270 | $\phi_S$ | 90° |
| | | $\phi_T$ | Δ |
| | | $\theta_T$ | 90° |

FIG. 14. Haigh Half-Wrap Antenna Roll Plane Pattern.

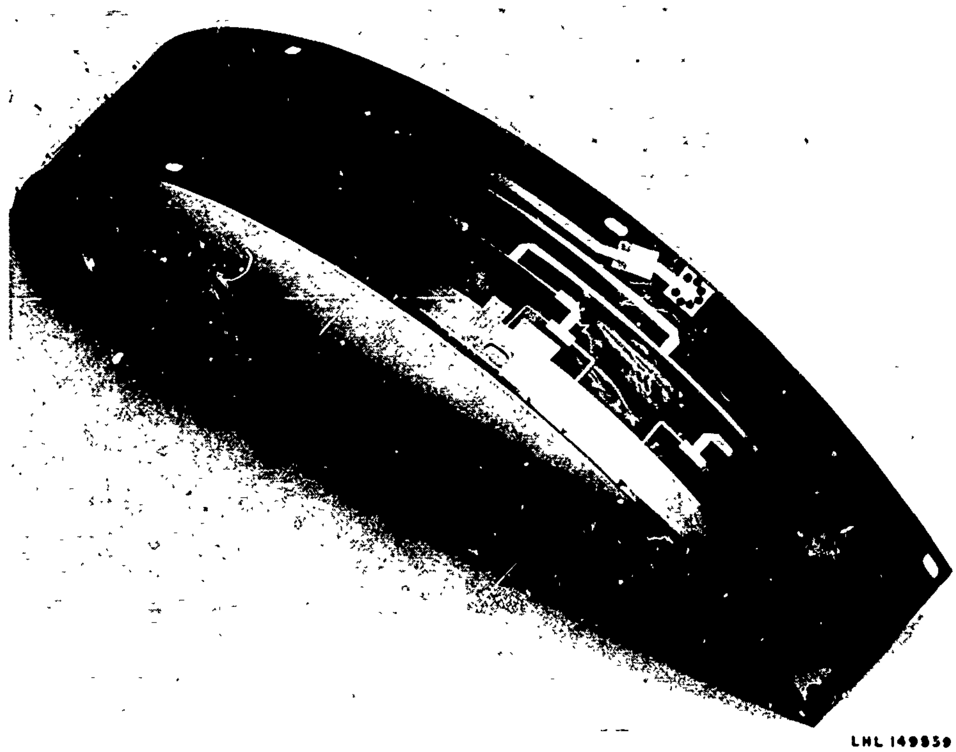


FIG. 15. Ball Brothers Wrap-Around Antenna

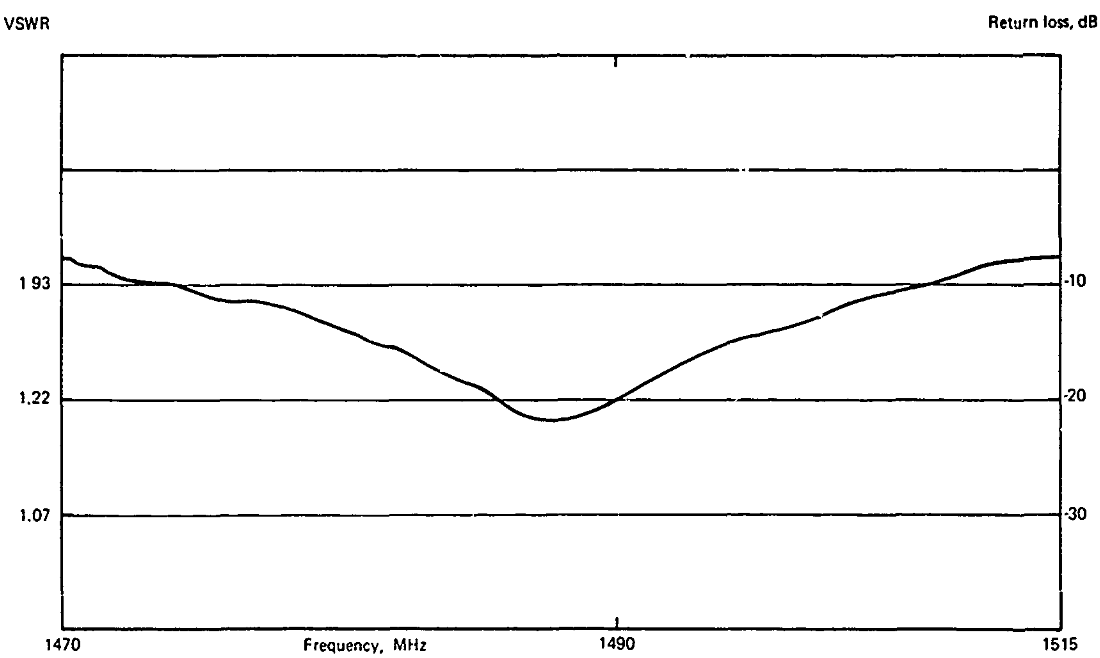
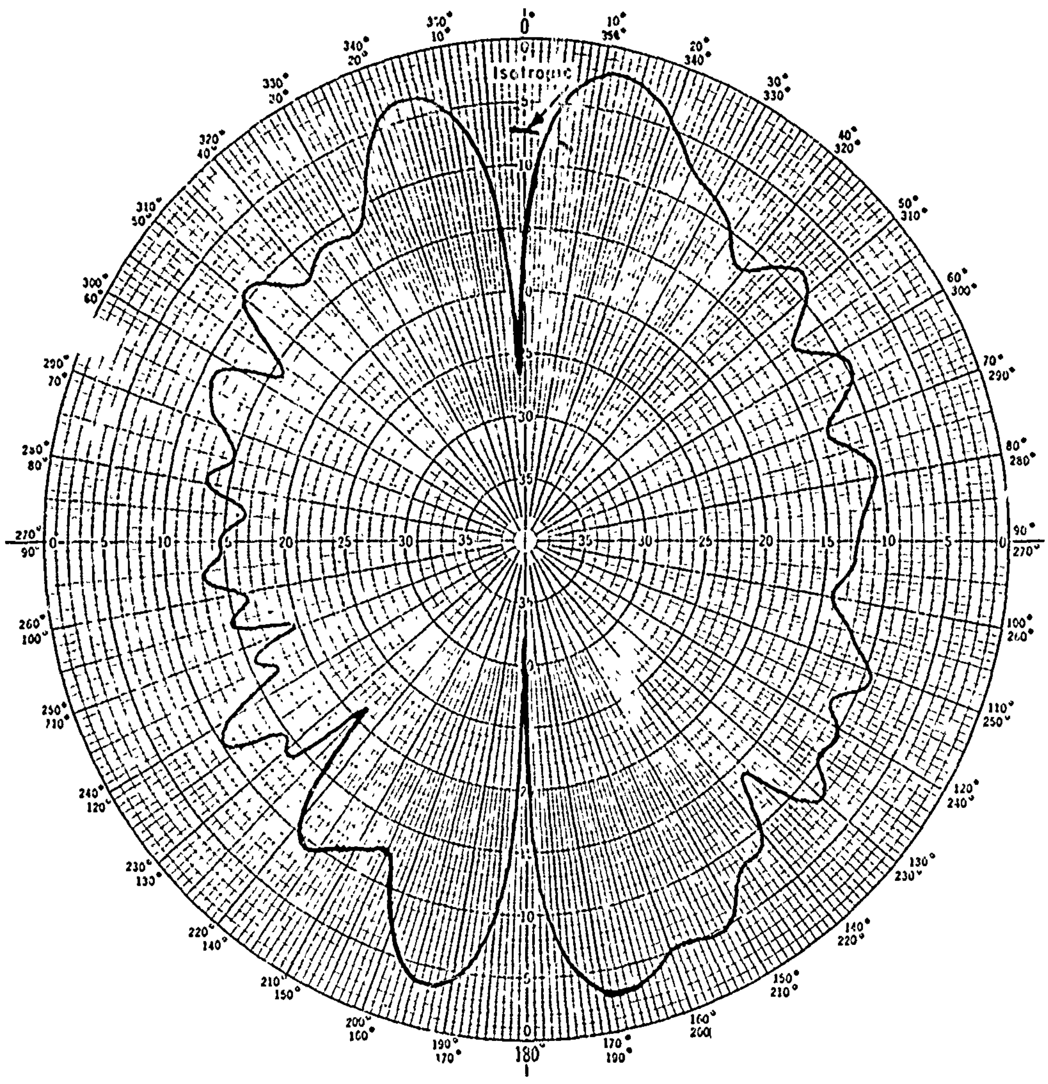
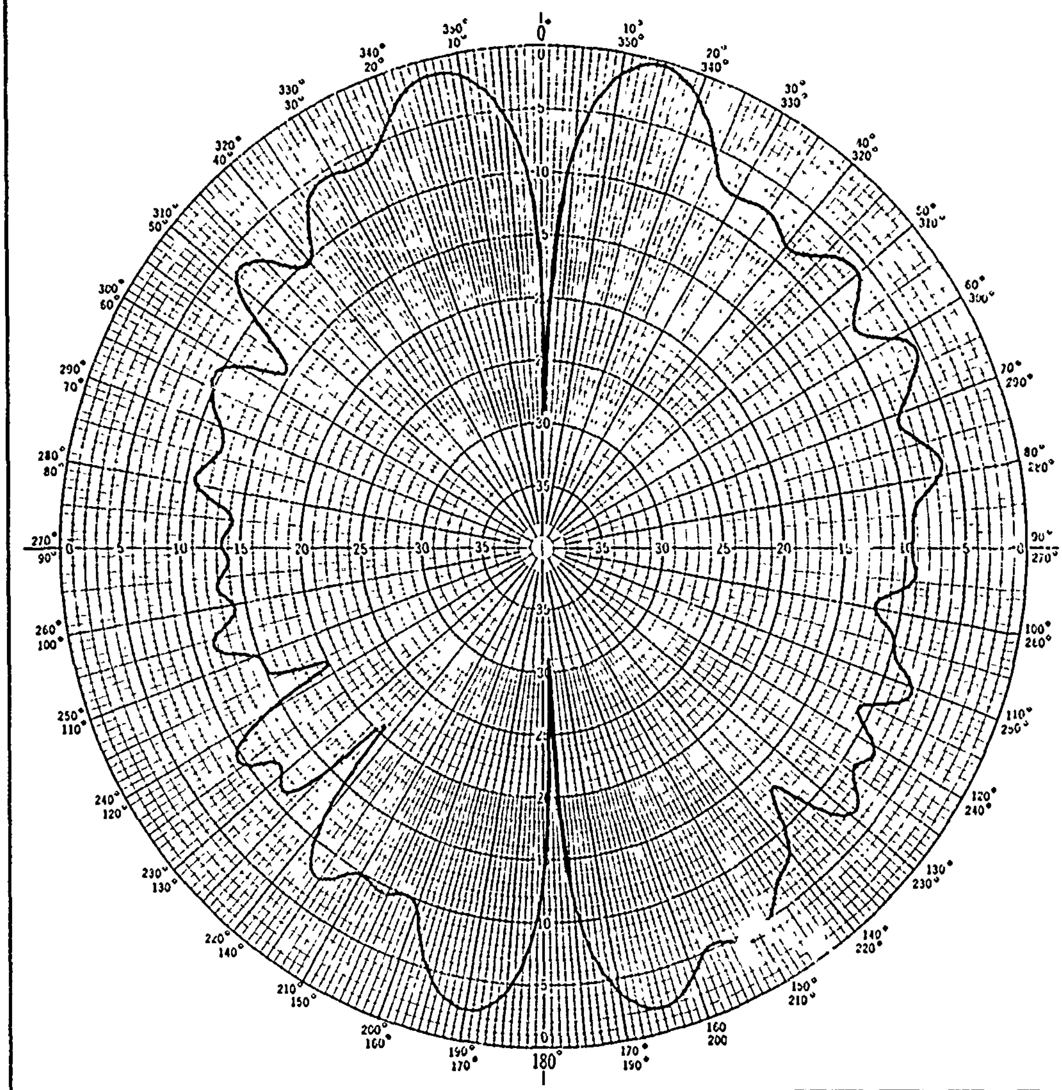



FIG. 16. VSWR/Return Loss of Ball Brothers Antenna.




| | |
|---|---|
| Ball Brothers Antenna | |
| November 5, 1970 | |
| Freq. 2207.5 | $\phi_s$ 90° |
| | $\phi_T$ 0° |
| | $\Theta_T$ Δ |

FIG. 17. Ball Brothers Antenna Yaw Plane Pattern.




| | |
|---|---|
| Ball Brothers Antenna | |
| November 3, 1970 | |
| Freq. 2207.5 | $\phi_S$ 90° |
| | $\phi_T$ 90° |
| | $\Theta_T$ Δ |

FIG. 18. Ball Brothers Antenna Pitch Plane Pattern.

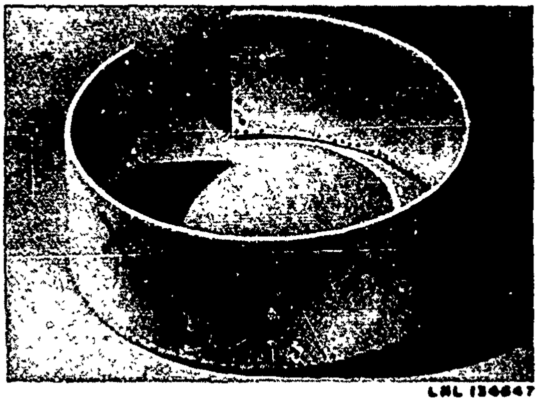



FIG. 19. Litton Wrap-Around Antenna.

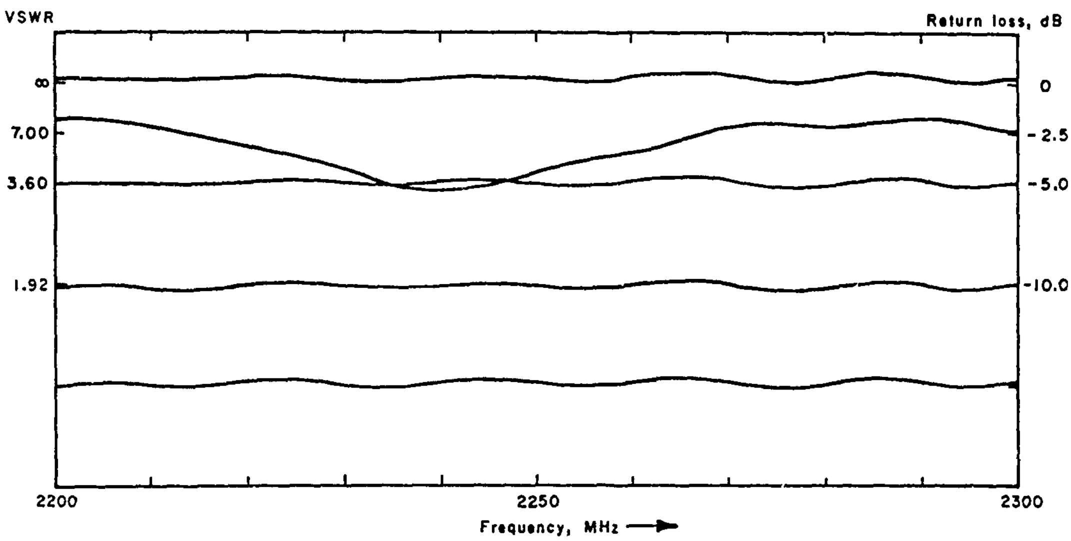
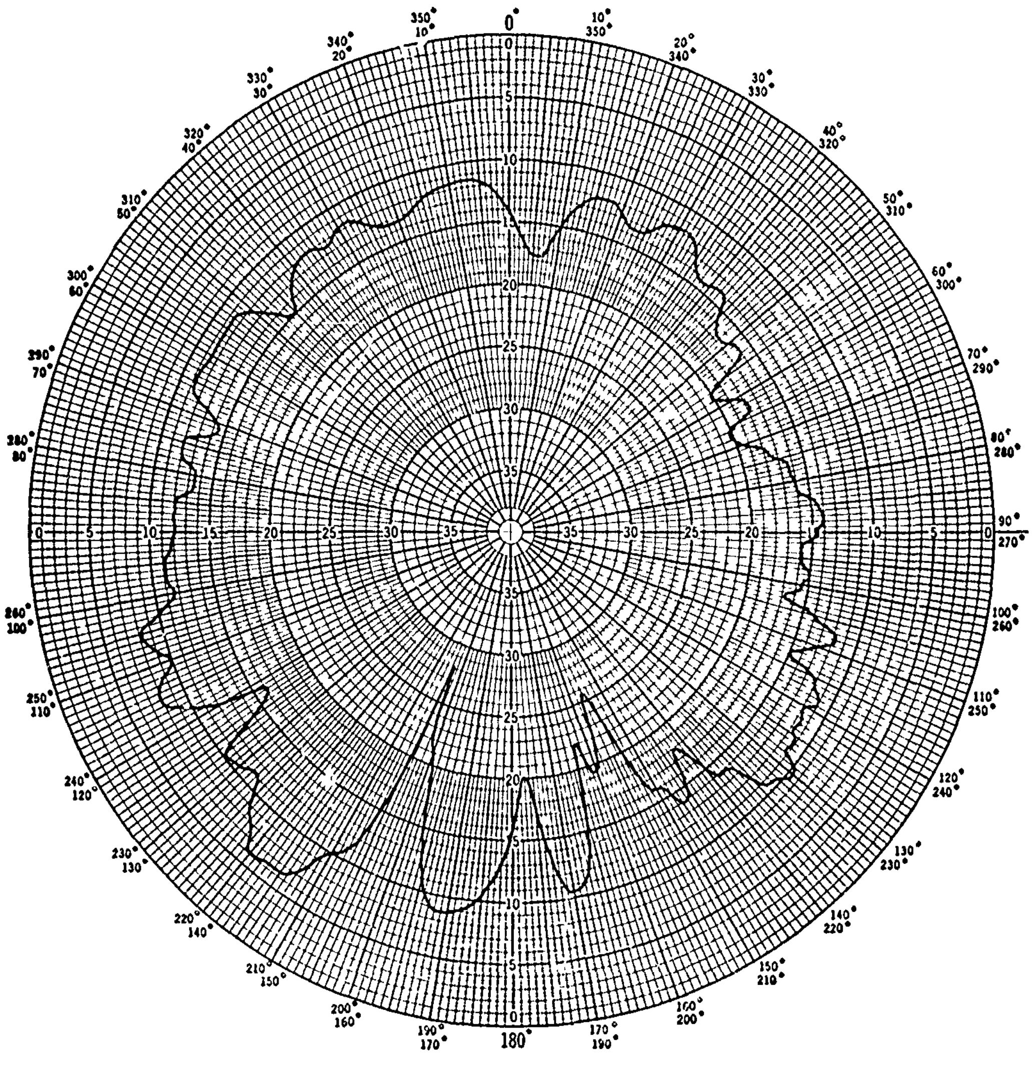
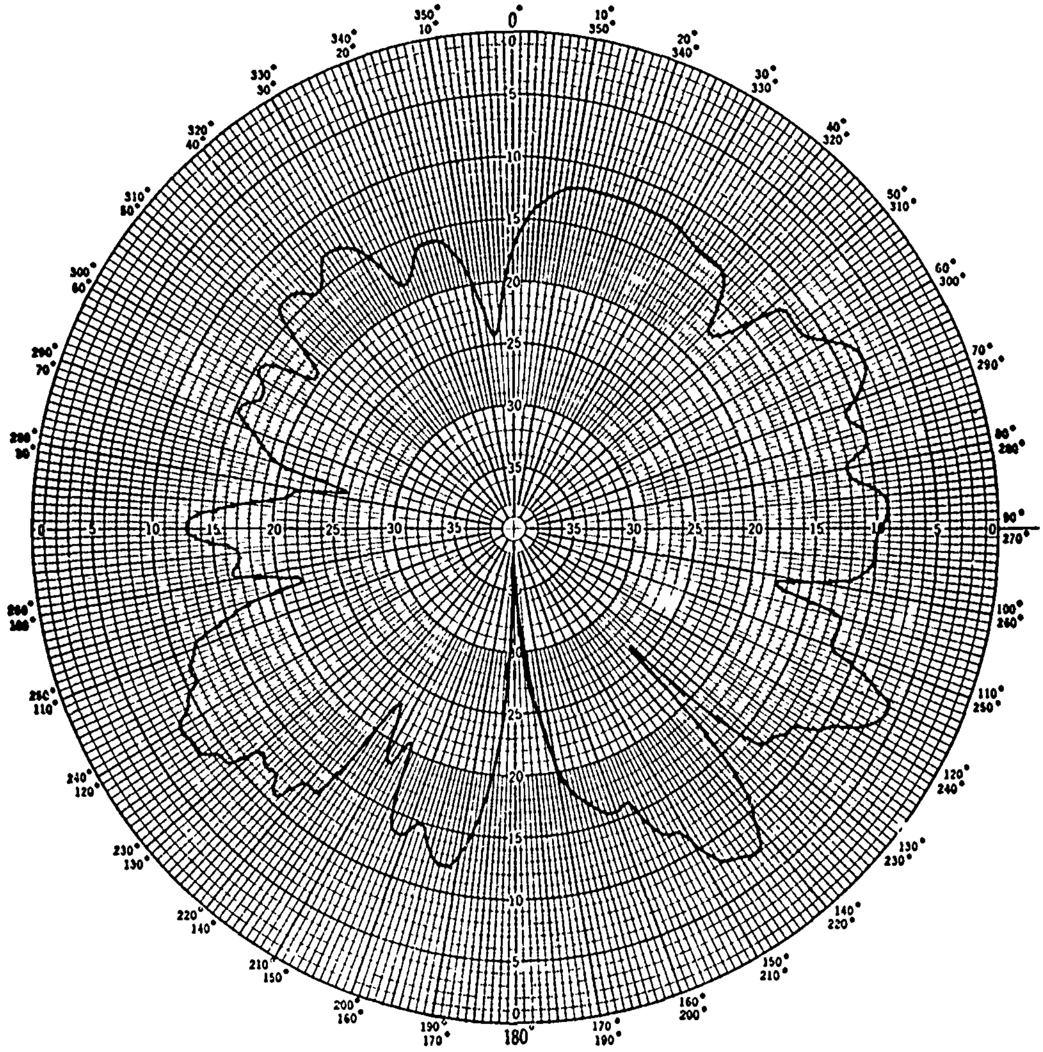



FIG. 20. VSWR/Return Loss of Litton Antenna.



| Litton Antenna #1 | | |
|---|---|---|
| March 21, 1968 | | |
| Freq. 2245.5 | $\phi_S$ | 90° |
| Pwr. Ref. +30 | $\phi_T$ | 0° |
| | $\Theta_T$ | Δ |

FIG. 21. Litton Antenna Yaw Plane Pattern.




| | | | |
|---|---|---|---|
| Litton Antenna #1 | | | |
| March 21, 1968 | | | |
| Freq. | 2245.5 | $\phi_s$ | 90° |
| Pwr. Ref. | +30 | $\phi_T$ | 90° |
| | | $\Theta_T$ | Δ |

FIG. 22. Litton Antenna Pitch Plane Pattern.

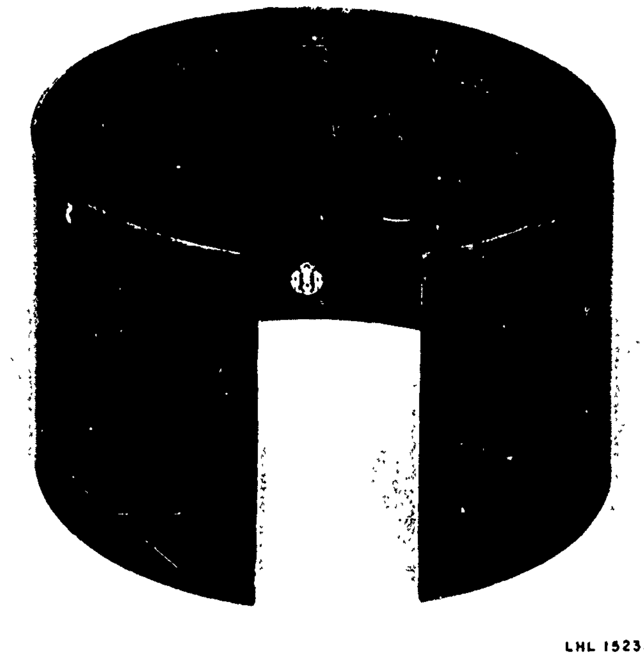



FIG. 23. NWCC Wrap-Around Microstripline Antenna.

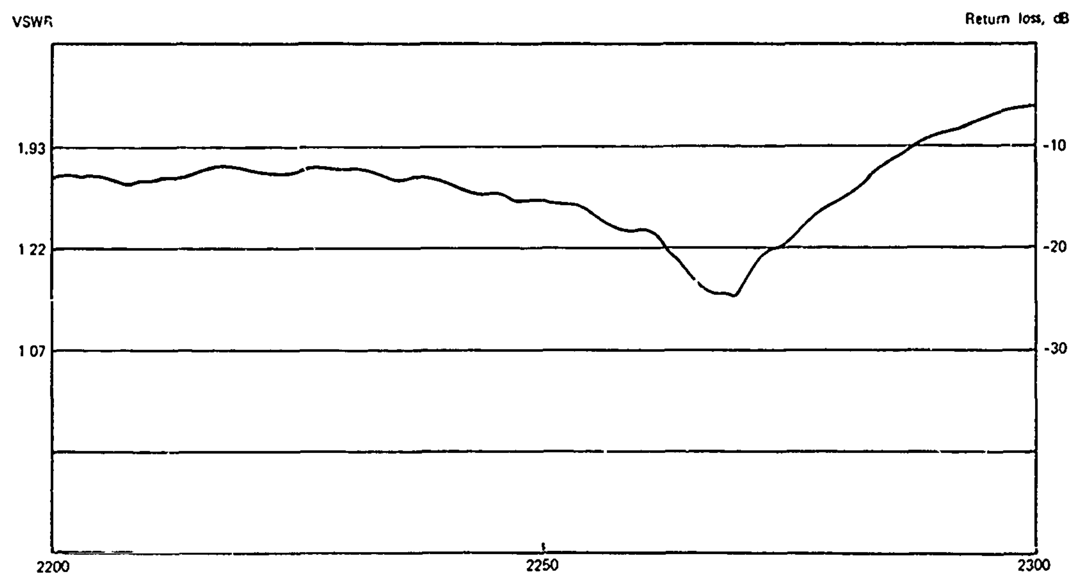
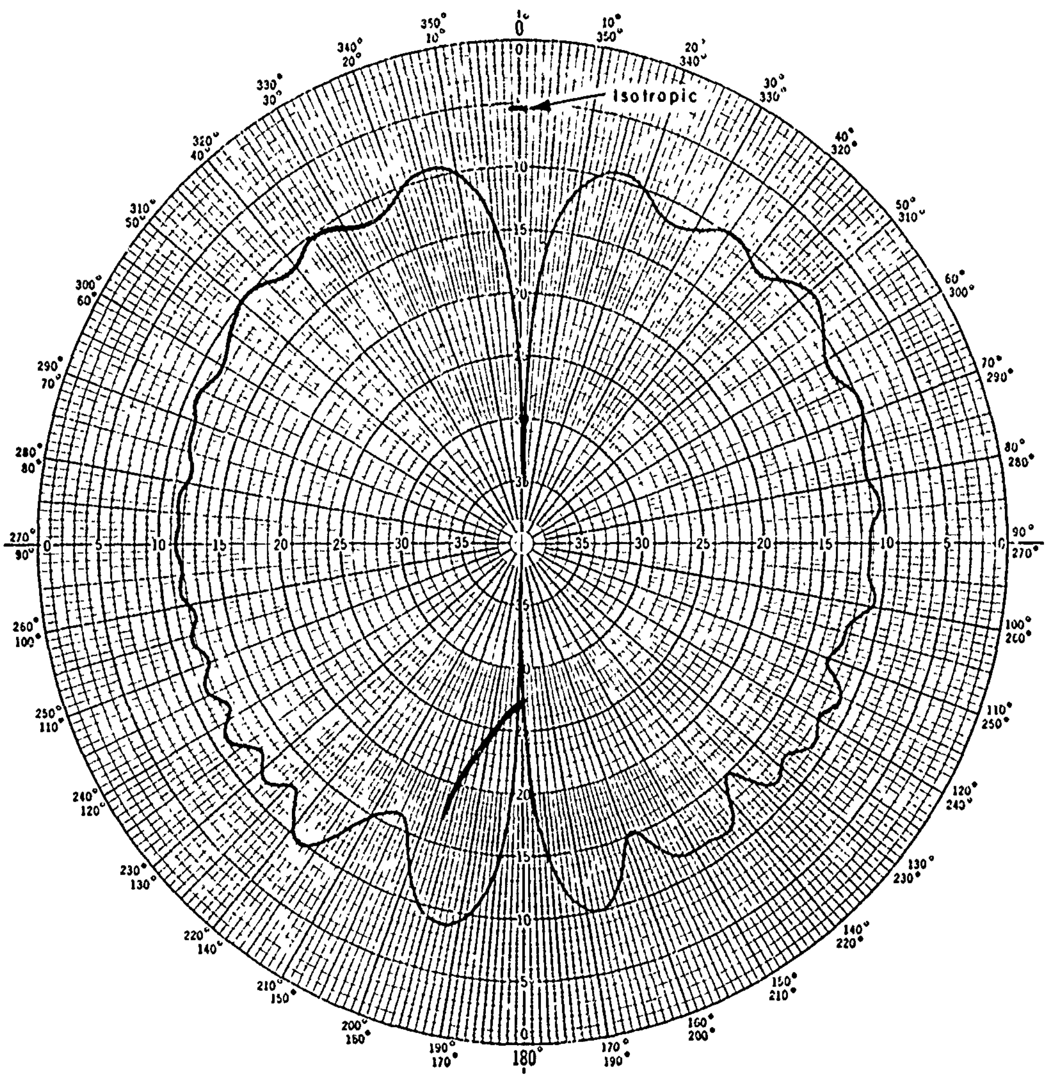
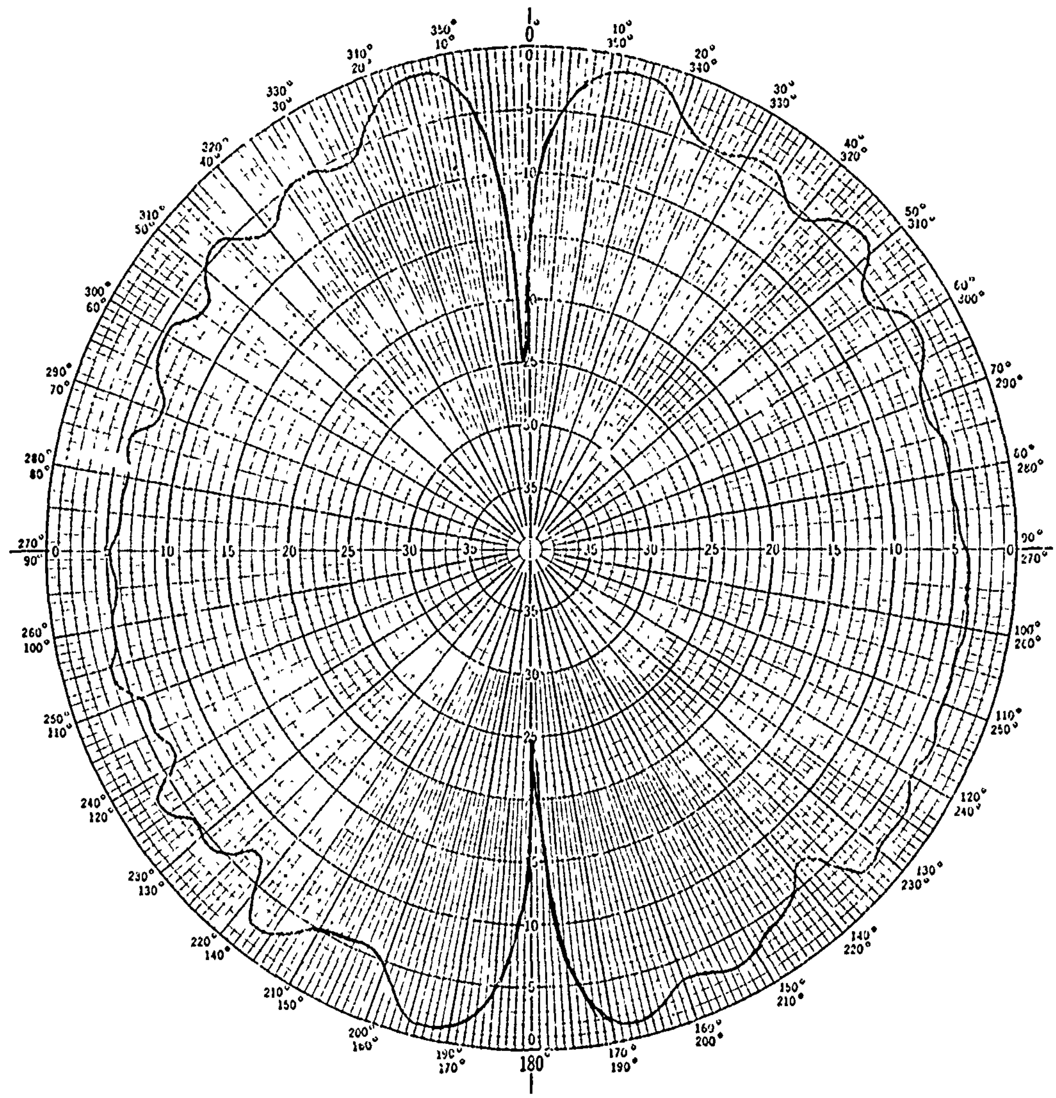



FIG. 24. VSWR/Return Loss of NWC Corona Antenna.




| | | |
|---|---|---|
| NWCC Antenna | | |
| October 21, 1970 | | |
| Freq. 2250 | | $\phi_S$ 90° |
| | | $\phi_T$ 0° |
| | | $\Theta_T$ Δ |

FIG. 25. NWCC Antenna Yaw Plane Pattern.




| | | |
|---|---|---|
| NWCC Antenna | | |
| October 21, 1970 | | |
| Freq. | 2250 | $\phi_S$ 90° |
| | | $\phi_T$ 90° |
| | | $\Theta_T$ Δ |

FIG. 26. NWCC Antenna Pitch Plane Pattern.

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ABSTRACT. This report documents the results of a program conducted to evaluate experimental and commercially available UHF airborne antennas for use in the 1435-1535 and 2200-2300 MHz telemetry bands. The evaluation established that a wrap-around type antenna gives satisfactory performance and is adaptable for use in several different missile configurations. The design and operational characteristics of each antenna evaluated in a missile configuration are presented, together with typical antenna patterns and VSWR data obtained during the program.


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| Wrap-around antennas | | | | | | |
| Antenna design | | | | | | |

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Evaluation of Airborne Telemetry Antennas for Use in UHF Telemetry Bands, by V. R. Christenson. China Lake, Calif., NWC, January 1971. 26 pp. (NWC TP 5099, publication UNCLASSIFIED.)

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